ON NUCLEAR STRUCTURE AND NUCLEAR MOMENTS (VI)

A. K. DUTTA

Palit Professor of Physics, Calcutta University,
92, Acharyya Prafulla Chandra Road, Calcutta-9.

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Nuclear moments which are determined by the structure of the nuclei, should give us, ultimately, the proper form of nuclear structure, when the magnitudes of these moments and their interrelations are clearly understood. In view of the accuracy of the experimental results, a suitable theory should approach the measured values closely. It is well known that the total orbital moments of the nuclei or their i-values are more or less in accordance with the shell model. Indeed the shell model is based on these measured i-values and the magic numbers and the agreement is expected. Even, then, there are disagreements of some experimental i-vaues (Strominger *et al*, 1958) with the allowed values proposed initially in each group. The already known moments of the nuclei F^{19}, Na^{23}, Mn^{55} and the more recently determined moments of Ne^{21}, Ti^{47}, Se^{79}, Hf^{179} contradict the allowed values, with an agreement for 3 out of 6 measured values in $2d_{5/2}$ shell, uptil now. Further, the interrelation between the orbital and magnetic moments expected on shell theory, on the basis of Schmidt model (Schmidt, 1937) is not supported by experimental values, although there are attempts to explain them. This has been clearly pointed out by Blatt and Weisskopf (1952, p. 772). Other procedures for correlating "i" and "μ" values (Rose and Bethe 1937, Margenau and Wigner 1940) have not proved to be of much consequence. The explanation of quadrupole moments, on any theory, is yet in a very unsatisfactory position, inspite of some attempts at explanation on shell theory (Gordy 1949, Hill 1949, Townes 1949). It is, therefore, quite reasonable to state that we have not yet understood nuclear structure as we have failed to correlate the nuclear moments and even to put forward a satisfactory explanation for the origin of rapidly fluctuating quadrupole moments with mass number.

It would perhaps be helpful to study the experimental findings on the "i" and "μ" values and their interrelation for different nuclei, critically, before formulating any plan for their interrelations. To understand these interrelations it is considered advantageous to have an overall picture for the whole set of nuclei before partitioning them as light, medium and heavy nuclei. Before proceeding in that direction, we may accept the experimental values for the magnetic moments of proton and neutron as $+2.793$ and -1.913 respectively, giving us the corresponding Lande-g-factors as 5.59 and -3.83 respectively. The Lande g-factors for the orbital moments of the proton and the neutron are considered generally, to be 1 and 0 respectively, on the basis of our knowledge of electrodynamic relations. In view of various complicated relationships cropping up in the nuclear dimensions it would have been better if these g-factors could be substantiated on grounds of experimental results and they are actually so substantiated as would be shown in the following.

We tabulate for this purpose the numbers of nuclei observed with an approximate value of μ for the different "i" values (Strominger *et al*, 1958), both for the odd proton and the odd neutron nuclei, as shown in Table I. The outlying rare cases have been left out in this tabulation.

TABLE I

	Numbers(odd proton nuclei)							Numbers (odd neutron nuclei)				
$i \downarrow$ $\mu \rightarrow$	$-.2$	.5	1.5	2.5	3.5	4.5	5.5	-1	.5	0	$+.6$	$+1$
1/2	6	0	4					3	3	4	8	0
3/2		10	3	10				1	4	0	3	2
5/2			5	2	8			4	6	0	3	2
7/2				8	0	6		3	4	1	2	1
9/2						1	4	4	1	0	0	0

It would be seen from the table that the major groups for odd proton nuclei lie on diagonal lines, decreasing the magnetic moment "μ" by unity for a corresponding decrease in the "i" value, whereas for nuclei with odd neutron, the major groups do not seem to change their magnetic moments when the "i" value is decreased by nuity. The tabulated values, therefore, substantiate from experimental data the generally held ideas about the Lande-g-factors for orbital motion of protons and neutrons, in a gross way. Further, the table indicates that the behaviour of light and heavy nuclei, which are all mixed up here, are perfectly alike in their interrelation between "i" and "μ" values and only one general principle of interrelation between these moments should hold for all nuclei.

Secondly, one finds from the tabulated values (Strominger *et al*, 1958) a small and systematic change in the magnetic moments of isotopic nuclei with the same "i" values. To cite only a few cases we have the observed data for 'i' and 'μ' as follows: $17Cl^{35,37}$, (3/2), .8, .68; $47Ag^{105,111}$, (1/2), $-.11$ to $-.14$; $50Sn^{115,119}$, (1/2), $-.9$ to 1.04; $56Ba^{135,137}$, (3/2), .83, .93. Such a change for isotopic nuclei with the same "i" values, is likely to be caused only by a variation of values of gyromagnetic- ratio for spinning motion, with the neutron content of the nuclei. The data, in general, tend to require that the magnetic moment for spin of the proton should vary from 2.8 to 2.5 units and that for spin of the neutron should change from -1.85 to -2.15, with increase of neutron content of the nuclei. The requirement of some such, correction is well known in connection with the

$i-$ relationship for 1H^{2}, and have been discussed by Blatt and Weisskopf (1952, p. 251).

We may now consider the process of development of nuclear structure (Dutta V. 1964), discussed before and try to find how far the observed magnetic and quadrupole moments are in accordance with that scheme of development. For this purpose we consider all nuclei upto a charge content of 5 units as primary and the rest as compositions from them, with additional neutrons. The nuclei 4Be^{8}, 6C^{12,13}, 7N^{11,15} have been considered as doubled up structures from the point of view of their binding energies.

Any even-even nucleus would be regarded as a composition of two groups of nuclei, with opposite moments to balance each other and give the resultant effect as zero, in accordance with observed results. When one considers the moment of nuclei on any other basis than the one particle model, it would be difficult to obtain neutralised effects for all even-even nuclei. It is also known that one particle model does not satisfy the reauirement of $i-\mu$ relationship for all nuclei. Group formation with opposite moments is thus, the only other alternative for all even-even nuclei.

For odd mass nuclei, we consider the development of structure as superposition of epuivalent groups, with opposite moments, on the primary nuclei, beginning from neutrons and protons at the earlier stages. Additional groups, symmetrically placed would then build up heavier nuclei. Thus, from oxygen nucleus, onwards, we may have two groups of 4Be^{8}, with opposite moment., superposed on the primary nuclei to compose heavier nuclei, at the initial stage. In such a case there should be close correspondence between the magnetic moments of the base and the composed nuclei. A variation in the orbital quantum number for the developed structure is not unlikely, changing the orbital and magnetic moments by integral numbers and thus the correspondence would be in the non-integral portions. Small changes due to the neutron content, as already pointed out, is also expected. From these points of view, the magnetic moments of a set of nuclei, which may be considered as the base and the composed structure, make favourable comparison as follows :

Nuclei	μ	Nuclei	μ
On^{1}	-1.92	3Li^{7}	3.26
8O^{17}	-1.90	11Na^{23}	2.20
		19K^{39}	0.30
1H^{3}	2.79		
9F^{19}	2.60	4Be^{9}	-1.18
		12Mg^{25}	-0.85
3Li^{6}	0.82	20Ca^{43}	-1.30
11Na^{22}	1.75	5B^{11}	2 69
6C^{13}	0.70	13Al^{27}	3.60
14Si^{29}	0.55	21Sc^{45}	4.7

It must be noted, however, that one cannot go on adding small nuclei to heavier nuclei for composition, as those would be gradually more composite in structure, so as not to form bonds with smaller groups.

We may note, further, that the doubled up structures of $6C^{13}$ and $7N^{15}$ make $14Si^{29}$ and $15P^{31}$, as four group nuclei instead of the three group nuclei of $13Al^{27}$, with 4 : 5 : 4 units of charge. One may consider that the three group system is saturated at Al^{27} and is followed by four and five group systems. From the nature of charge distribution and charge saturation, such nuclei should have comparatively large quadrupole moments as observed and weaker binding represented by a maximum of the $F(Z)$ curve, shown in previous works (Dutta and others IV, 1964). It is expected to be followed by a comparative spread of the group and negative quadrupole moment, as in 3 : 3 : 5 : 3 : 3 charge distribution proposed for chlorine nucleus. The maxima of the $F(Z)$ curve, near mass numbers 59, 117, 177 and 235, already noted (Dutta IV, V) are associated with large values of quadrupole moments in these positions. They correspond to the charges 27, 49, 71 and 92 and should be followed by a possible change over in structural groups, suitable for even and odd charges, which are symmetrically placed and held together by mutual bonds. These considerations would be substantiated.

It may be pointed out also that large quadrupole moments for even charge nuclei are very often not associated with those for the odd charge nuclei. This should be on account of the particular group systems and the characteristics of particular compositions necessary for odd and even nuclei. They obtain large positive or negative quadrupole moments for these nuclei by correlation with the concentration of charge in a structure, as has been just indicated. The large quadrupole moment at $34Se^{79}$ corresponds perhaps to the saturation of some even -group system. Odd charge nuclei has a subdued maxima in this region.

It may be remarked, finally, that with appropriate orbital and spin quantum numbers, associated with the major subdivisions, one may build up the magnetic moments of all nuclei by superposition of structures, keeping in view the observed quadrupole moments also. What is necessary and of importance however, is to associate the changes in quantum numbers with associated properties. The problem is being looked into.

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